1. A microwave oven operating at $1.22 \times 10^8$ nm is used to heat 150 mL of water from 20°C to 100°C. What is the number of photons needed if all the microwave energy is converted to thermal energy of water? [Density of water = 1.00 g/mL]

\[
\begin{align*}
M &= V \cdot \text{Density} = 150 \text{ mL} \cdot \frac{1.00 \text{ g}}{1 \text{ mL}} = 150 \text{ g} \\
\Delta T &= 100 - 20 \\
q &= 5m\Delta T = 4.184 \frac{J}{\text{g}^\circ\text{C}} \times 150\text{ g}(80^\circ\text{C}) = 50208 \text{ J} \\
E &= h \frac{c}{\lambda} = \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s} \cdot 3 \times 10^8 \text{ m/s}}{1.22 \times 10^{-6} \text{ m}} = 1.63 \times 10^{-26} \text{ J}
\end{align*}
\]

(A) $3.08 \times 10^{28}$
(B) $4.07 \times 10^{27}$
(C) $1.63 \times 10^{28}$
(D) $5.46 \times 10^{27}$
(E) $5.02 \times 10^{27}$

2. What is the wavelength of light required to remove an electron from a sample of potassium (K) metal, if the binding energy for an electron in potassium is $1.76 \times 10^3$ kJ/mol?

\[
\begin{align*}
\hbar \nu &= h \frac{c}{\lambda} + \omega \\
\hbar \frac{c}{\lambda} &= \omega
\end{align*}
\]

(A) 68.0 nm
(B) 18.8 nm
(C) 147 nm
(D) 113 nm
(E) 885 nm

$\lambda = \frac{h}{m} = 1469 \text{ nm} \rightarrow \lambda = 6.8 \times 10^{-9} \text{ m} = 68.0 \text{ nm}$

3. Which one of the following sets of quantum numbers can correctly represent a 3p orbital?

<table>
<thead>
<tr>
<th>i</th>
<th>ii</th>
<th>iii</th>
<th>iv</th>
<th>v</th>
</tr>
</thead>
</table>
| $n = 3$ | $\ell = 1$ | $m_l = -1$ | $
\begin{align*}
\ell &= 1 \\
m_l &= 1 \\
\end{align*}$
| $n = 3$ | $\ell = 2$ | $m_l = 1$ | $
\begin{align*}
\ell &= 2 \\
m_l &= 0, -1, 1
\end{align*}$

(A) iv
(B) v
(C) i
(D) ii
(E) iii

3p : $n = 3$
\[\ell = 1\]
\[m_l = -1, 0, 1\]
4. A proton is accelerated to one-tenth the velocity of light, and this velocity can be measured with a precision of 1%. What is the uncertainty in the position of this proton? [The mass of the proton is $1.673 \times 10^{-27}$ kg]

\[
A = \frac{1}{10} c = \frac{1}{10} (3.0 \times 10^8 \text{ m/s}) = 3.0 \times 10^7 \text{ m/s}
\]

\[
\Delta u = 3.00 \times 10^7 \text{ m/s} \times 0.01 = 3.00 \times 10^5 \text{ m/s}
\]

5. The speed of an electromagnetic wave

A) depends on the type of the wave and the nature of the medium. — True
B) always constant and equals to $3.00 \times 10^8$ km/s. — True
C) depends on the frequency of the wave. — False
D) depends on the nature of the medium only. — False
E) depends on the amplitude of the wave. — False

6. Arrange the following in order of increasing first ionization energy: F, K, P, Ca, and S.

The order of increasing first ionization energy (lowest to highest) is:

A) K < Ca < S < P < F
B) S < Ca < P < F < K
C) S < F < P < Ca < K
D) S < K < P < F < Ca
E) K < Ca < P < S < F

7. An M$^{2+}$ ion derived from a metal that has four electrons in the 3d subshell. What element might M be?

\[
[Ar] 3d^4 = M^{2+} \Rightarrow Cr^{2+}
\]

A) Chromium (Cr)
B) Manganese (Mn)
C) Scandium (Sc)
D) Titanium (Ti)
E) Iron (Fe)
8. Of the following, which element does not match its designation?

A) In (Atomic number 49) / representative nonmetal
B) Sr (Atomic number 38) / representative metal
C) Si (Atomic number 14) / metalloid
D) Mo (Atomic number 42) / d-transition metal
E) U (Atomic number 92) / f-block (transition) metal

Yes

9. Which of the following statement(s) is/are false?

I. Electrons in inner shells screen or shield electrons in outer shells from the full effect of the nuclear charge. **True**
II. The effective nuclear charge experienced by an electron in an outer shell is more than the actual nuclear charge. **False**
III. The atomic radii of representative elements increase from left to right across a period (i.e., horizontal row in the periodic table) **False** Decreases

A) II and III only
B) I and II only
C) All of them
D) I only
E) III only

10. Which one of the following species is not isoelectronic with neon (Ne)?

A) Si²⁺
B) Al³⁺
C) Na⁺
D) O²⁻
E) Mg²⁺
11. Use the following data to calculate $\Delta H_f^\circ$ for barium bromide.

Lattice energy +1985 kJ/mol
First ionization energy of Ba +503 kJ/mol
Second ionization energy of Ba +965 kJ/mol
Enthalpy of electron affinity of Br -325 kJ/mol
Bond energy of Br$_2$ +193 kJ/mol
Enthalpy of sublimation of Ba +178 kJ/mol

\[
\begin{align*}
\text{A)} & \quad -796 \text{ kJ/mol} \\
\text{B)} & \quad -146 \text{ kJ/mol} \\
\text{C)} & \quad -603 \text{ kJ/mol} \\
\text{D)} & \quad -618 \text{ kJ/mol} \\
\text{E)} & \quad -554 \text{ kJ/mol}
\end{align*}
\]

12. Which of the following compounds has/has expanded octet Lewis structure(s)?

\[
\begin{align*}
\text{XeF$_2$} & \quad & \text{XeF$_4$} & \quad & \text{SF$_4$} \\
\text{A)} & \quad \text{I, II and III} & \quad & \text{II} & \quad & \text{III}
\end{align*}
\]

\[
\begin{align*}
\text{A)} & \quad \text{I, II and III} \\
\text{B)} & \quad \text{II and III only} \\
\text{C)} & \quad \text{I and II only} \\
\text{D)} & \quad \text{II only} \\
\text{E)} & \quad \text{III only}
\end{align*}
\]

13. Use the given bond energies to estimate $\Delta H$ for the following reaction:

\[
\text{HCN(g)} + 2\text{H}_2(g) \rightarrow \text{CH}_3\text{NH}_2(g)
\]

\[
\text{Bond Energies (kJ/mol)}:
\begin{align*}
\text{H–C:} & \quad 413; \quad \text{C–N:} \quad 305; \quad \text{C=N:} \quad 615; \quad \text{C≡N:} \quad 891; \quad \text{H–H:} \quad 432; \quad \text{N–H:} \quad 391.
\end{align*}
\]

\[
\begin{align*}
\text{A)} & \quad -158 \text{ kJ} \\
\text{B)} & \quad -590 \text{ kJ} \\
\text{C)} & \quad +590 \text{ kJ} \\
\text{D)} & \quad +214 \text{ kJ} \\
\text{E)} & \quad -434 \text{ kJ}
\end{align*}
\]

\[
\Delta H = \sum BE_{\text{reaction}} - \sum BE_{\text{products}} = (1(413) + 1(891) + 2(432)) - (3(413) + 1(305) + 2(391)) = 2168 - 2326 = -158 \text{ kJ}
\]

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\[ \begin{align*}
\text{BaBr}_2(s) & \rightarrow \text{Ba}(s) + \text{Br}_2(g) = ? \\
\text{Ba}(s) & \rightarrow \text{Ba}(g) = +178 \\
\text{Br}_2 & \rightarrow 2\text{Br} = +193 \\
\text{Br}_2(g) & \rightarrow \text{Br}_2^+(g) + e^- = +503 \\
\text{Br}_2^+ & \rightarrow \text{Br}_2^{2+} + e^- = +965 \\
2\text{Br} + 2e^- & \rightarrow 2\text{Br}^- \\
\text{BaBr}_2(s) & \rightarrow \text{Ba}^{2+}(g) + 2\text{Br}^-(g) = 1985 \\
2(-375) & = -750 \\
1985 & = (-\Delta H_f^0) + 178 + 193 + 503 + 965 - 750 \\
\Delta H_f^0 & = -796 \text{ KJ/mol} \\
\text{Problem #11} &
\end{align*} \]
14. Which set of elements is arranged in order of increasing electronegativity (lowest to highest)? In, O, S, As

A) In < As < S < O
B) O < S < As < In
C) S < O < As < In
D) As < O < In < S
E) S < In < O < As

15. Choose the correct statement about the compound SO₂:

A) The S atom has an unshared electron pair.
B) The S-O bonds are 100% ionic in character.  
C) The two S-O bonds have different lengths since one is a single bond and the other is a double bond.  
D) The molecule has a linear structure.  
E) The O atoms have no unshared electron pairs.

16. The heat of solution (heat of dissolving) of an ionic solid in water is +20.3 kJ/mol. If enough quantity of ionic solid is added to water at 23.5 °C in a Styrofoam cup to produce 150.0 mL of 2.50 M solution, what will be the final temperature? (Assume the solution has a density of 1.88 g/mL and a specific heat of 2.70 J/g·°C).

A) 13.5 °C
B) 12.2 °C
C) 13.9 °C
D) 13.5 °C
E) 13.5 °C

17. Which one of the following statements is INCORRECT?

A) Kinetic energy is the energy that results from an object’s position.  
B) Energy is the capacity to do work.  
C) Energy is neither created nor destroyed in chemical reactions.  
D) Exothermic processes transfer heat from the system to the surroundings.  
E) Increasing the thermal energy of a gas increases the motion of its atoms.
18. How many moles of methanol (CH₃OH) are needed to produce 944.5 kJ of energy, according to the following data:

\[ 2\text{CH}_3\text{OH}(l) + \frac{3}{2}\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 4\text{H}_2\text{O}(l) \]

\[ \Delta H^\circ_{f}(\text{H}_2\text{O}) = -285.8 \text{ kJ/mol} \]
\[ \Delta H^\circ_{f}(\text{CO}_2) = -393.5 \text{ kJ/mol} \]
\[ \Delta H^\circ_{f}(\text{CH}_3\text{OH}) = -238.7 \text{ kJ/mol} \]

\[ \Delta H = \sum n \Delta H^\circ_{f} \text{prod} - \sum n \Delta H^\circ_{f} \text{react} \]
\[ = \left[ 2(-393.5) + 4(-285.8) - (2(-238.7) + 0) \right] \]
\[ = -1930.2 + 477.4 \text{ kJ/mol} \]
\[ = -1452.8 \text{ kJ/mol} \]

A) 1.300 mol
B) 2.599 mol
C) 1.233 x 10⁻³ mol
D) 3.123 x 10⁻³ mol
E) 2.332 x 10⁻³ mol

\[ \text{mol CH}_3\text{OH} = \frac{944.5 \text{ kJ}}{1452.8 \text{ kJ/mol}} = 0.65 \text{ mol CH}_3\text{OH} \]

19. The expansion of a gas in volume from 45.0 mL to 200.0 mL against vacuum absorbs a heat of 3.0 J. Calculate the change in energy associated with this process.

\[ \Delta U = \Delta q + \Delta w = q - \rho \Delta V \]
\[ \Delta U = 3 \text{ J} \]

A) +3.0 J
B) -3.0 J
C) +155 J
D) -155 J
E) -152 J

20. Calculate the ratio of heat required to increase the temperature from 280 K to 300 K of a water sample to that of aluminum, when the same quantities of them are heated. The specific heats of water and aluminum are 4.184 and 0.900 J/g . °C, respectively.

\[ q = \Delta m \Delta T \]
\[ \frac{q_1}{q_2} = \frac{4.184 \left( \frac{280}{290} \right) \text{ (m)} \left( 20 \text{ °C} \right)}{0.900 \left( \frac{280}{300} \text{ (m)} \left( 20 \text{ °C} \right) \right)} \]

\[ \frac{q_1}{q_2} = 4.65 \]